UNCLASSIFIED

AD NUMBER

AD861832

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; OCT 1969. Other requests shall be referred to Office of Naval Research, Arlington, VA.

AUTHORITY

ONR ltr, 28 Jul 1977

THIS PAGE IS UNCLASSIFIED

1

SU-SEL-69-064

A Single-Antenna Repeater for HF Radio Propagation Studies

by

A. C. Phillips

October 1969

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Office of Naval Research, Field Projects Programs, Washington, D.C. 20360.

TECHNICAL REPORT NO. 154

Prepared under
Office of Naval Research Contract
Nonr 225(64), NR 088 019, and
Advanced Research Projects Agency ARPA Order No. 196

RADIOSCIENCE LABORATORY

STANFORD ELECTRONICS LABORATORIES

STANFORD UNIVERSITY · STANFORD, CALIFORNIA

SEL-69-064

A SINGLE-ANTENNA REPEATER FOR HF RADIO PROPAGATION STUDIES

by

A. C. Phillips

October 1969

Technical Report No. 154

Prepared under
Office of Naval Research Contract
Nonr-225(64), NR 088 019, and
Advanced Research Projects Agency
ARPA Order No. 196

Radioscience Laboratory
Stanford Electronics Laboratories
Stanford University Stanford, California

ABSTRACT

The purpose of the work described in this report was to develop and test a compact, portable, calibrated single-antenna repeater which has application to HF radio propagation studies. For example, high-frequency backscatter ionograms--depending on the terrain--generally show one or more discrete range intervals where the returned energy is appreciably greater than the general noise-like return from other ranges. The ground features which cause these areas of enhanced HF energy reflection are not as yet fully understood. A portable repeater is capable of being operated in those areas where such reflections exist so that a direct comparison can be made between the repeated signal and the natural echoes. The repeater described in this report is especially useful with FMCW sounding waveforms.

A fundamental problem in building any repeater is the avoidance of oscillations when it is attempted to retransmit an amplified signal with receiving and transmitting antennas in the same locality. The solution adopted in this case consists of switching one antenna rapidly between transmitting and receiving modes. The received signal is amplified, then stored for the duration of the receiving period. At the end of that period it is transmitted. The act of switching in this way does not seriously degrade the operation of the repeater; in fact, it confers certain unique advantages.

The portable repeater described herein has been tested in the field, and has been found to perform satisfactorily.

CONTENTS

ILLUSTRATIONS

TABLES

I. INTRODUCTION

A. PURPOSE

The purpose of this report is to describe a single-antenna high-frequency (HF) repeater which is particularly useful in HF radio propagation studies where a compact, easily transported piece of equipment is required.

B. STATEMENT OF THE PROBLEM

The systems for which this work is relevant involve HF radio signals which have been propagated via the ionosphere. Studies of the properties of ionospheric propagation are aided by repeaters which retransmit amplified signals with some well-defined relationship to the incident radio waves.

High-frequency backscatter ionograms made with high-resolution sounders [Refs. 1,2] generally show discrete range and azimuth intervals wherein the backscatter energy is appreciably greater than the general level of noise-like return from most other range and azimuth intervals [Ref. 3]. This circumstance has been studied by Basler and Scott [Ref. 4].

If one had a repeater which could easily be transported to any part of the world, these areas of enhanced backscatter energy could be identified by making the repeater "echo" coincide with the position of the enhanced ground "echo". By observing the terrain at the repeater location, one could perhaps deduce what feature was distinctive about the area that might cause high coherent reflection of HF energy. Also, given the gain of the repeater, one could estimate the effective cross section of the ground reflector.

C. PROPOSED SOLUTION

The basic problem in building a repeater is the occurrence of oscillations when it is attempted to retransmit an amplified received signal with receiving and transmitting antennas in the same locality. The solution to this problem chosen here consists of switching rapidly between transmitting and receiving modes. The received signal is amplified,

then stored for the duration of the receiving period. At the end of that period it is transmitted. The repeated signal is therefore identical to the received signal except for delay and for the on-off keying which originates frequency components not in the received signal. When used with an FMCW sounding system, the device performs as an ideal repeater with delay, because the sidebands generated by the pulsing can be made to fall outside the FMCW receiver bandwidth.

II. DESCRIPTION OF THE DELAY-LINE REPEATER

A. PRINCIPLE OF OPERATION

The principle of operation of the delay-line repeater is illustrated by the block diagram shown in Fig. 1. A "transmit-receive" (TR) switch assigns the function of the antenna to alternating periods of transmitting and receiving. During the "receive" period the received signal is stored in analog form in a delay line. After a receiving time equal to or greater than the delay τ, the system transmits the amplified output of the delay line.

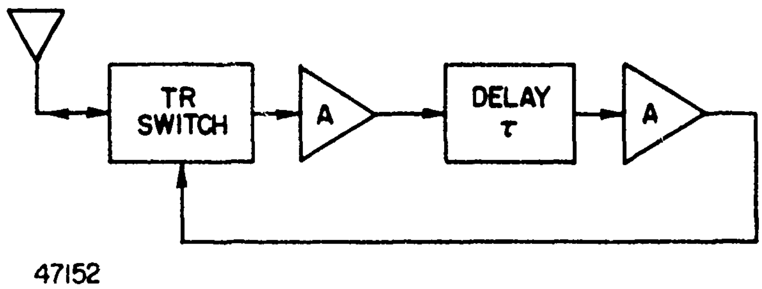


Fig. 1. DELAY-LINE REPEATER.

To prevent oscillations a dead period must be provided between the "transmit" and "receive" periods. This dead period can be accomplished by leaving the TR switch in the "receive" mode for a little longer than the delay time τ.

The signal transmitted by the repeater is equal to the delayed received signal, pulse-modulated and amplified. The spectrum of the transmitted signal is the same as that of the received signal, except that frequency components are repeated on each side of the received spectral components in proportion to, and positioned according to, the frequency components of the pulse modulation.

The delay-line repeater is expected to be particularly useful in sounding systems using transmissions having large time-bandwidth products, such as FMCW and coded pulse. For FMCW systems the receiver bandwidth is typically so narrow that the sidebands produced by the pulse modulation that originates in the repeater fall outside the receiving bandwidth, thus

making the delay-line repeater appear to be an ideal device for use in such systems.

B. DESIGN REQUIREMENTS

1. Pulse Width

A delay-line repeater could be designed to operate successfully with any sounding system having a transmitted waveform which has significant amplitude over a time at least twice the time delay of the delay line. Because of the dead time required between transmitting and receiving phases, a minimum pulse width to meet this condition would be about 50 μsec. The gain of the repeater for systems having pulses much longer than the time delay of the delay line is a linear function of the transmitting duty cycle. For waveforms which are only slightly longer than twice the delay-line delay, the effective gain of the repeater will vary depending on the relation between the time of the pulse and the repeater switching. For a repeating pulse whose repetition frequency is not a subharmonic of the repeater-switching frequency, the repeater gain will vary in beat-note fashion. If the pulse-repetition frequency is a subharmonic, the gain will be unknown between the limits of the beat variation above unless the phase of the repeater switching can be locked to a harmonic of the pulse-repetition frequency.

If synchronizing control is available to adjust the phase of the repeater switching in order to ensure that the repeater will be in the receiving mode when a pulse arrives, the above restriction on pulse width is removed, and the repeater will work for any pulse system. The equipment described in this report, however, would not be able to handle the peak power which would be required for a wide-bandwidth simple-pulse system (a "simple pulse" being one without phase or frequency modulation) having the same average power as an FMCW system.

Given a simple repetitive pulse system having a pulse shorter than the delay-line delay, and given that it is desired to make use of the simplicity of the delay-line repeater without any synchronizing control, the repeater echo could be made visible by randomizing the width

of the receiving period of the repeater. If alternating periods of repeater visibility and invisibility are acceptable it would be sufficient to have a non-random receiving period which results in a repeater switching rate which is not harmonically related to the sounder PRF.

For FMCW and simple-pulse systems which meet the requirements for application of the delay-line repeater, the repeater will perform as an ideal non-switching repeater, since the sidebands generated by its switching process are filtered out before the final data display. For a coded-pulse system, however, some spurious range sidelobes can be expected, since the pulse modulation in the repeater would degrade the quality of the autocorrelation function of the code.

2. Delay Line

The requirements for the delay line used in the delay-line repeater are easily met by employing an ultrasonic delay device having quartz or glass as the delay medium. These ultrasonic delay lines can be manufactured with a bandwidth in excess of 50 percent of their bandpass center frequency. The bandpass center frequency is selectable up to about 50 MHz. For extremely phase-stable repeating, the glass delay line is preferred because its temperature coefficient of delay is better than one part per minute per degree centigrade (1 ppm/°C), while the quartz has a temperature coefficient about equal to 70 ppm/°C.

Assuming a particular duty cycle, the amount of delay determines the rate of switching between the transmitting and the receiving modes. If this switching rate were too low, say less than 5 kHz, an audio tone would be produced in any fixed-station communicator that received the repeater signals. To avoid the occurrence of this very noticeable type of interference, it is desirable to use a delay having a value low enough to give a switching rate in excess of 5 kHz. However, if a switching rate much greater than that dictated by the interference consideration is used, the resulting duty cycle is decreased because of the necessity of leaving the TR switch in the "receive" position slightly longer than the delay τ. In view of these considerations, an appropriate value for the delay is between 50 μsec and 100 μsec.

3. Gain

To prevent loop oscillations, the attenuation in the "off" position of the TR switch must be greater than the loop gain.

The amplifier preceding the delay should have a gain in excess of the delay-line attenuation for two purposes:

1. To maintain the best possible ratio of received signal to circuit noise.
2. To minimize the gain between any two points in the system and thereby minimize the problems of leakage feedback.

The net loop gain must be adjustable to accommodate the varying path losses between the desired-signal transmitter and the repeater. Tests using a two-antenna repeater have shown that the maximum gain that would be required is less than 90 dB. In normal operation the gain would be adjusted to cause the output to be slightly below the output amplifier power capability.

In some cases it may be desirable to translate the received frequencies before retransmission in order to simplify detection of the repeater signal by causing its frequencies to fall outside the range of the ground backscatter. This frequency translation is easily accomplished by inserting a balanced diode mixer at a point within the repeater loop where the signal level is low.

C. INTERFERENCE CONSIDERATIONS

1. Interference by Repeater to Other Users of the HF Spectrum

The mere repeating of HF received signals would not be likely to cause annoyance to other users of the HF spectrum, since the probability would be small that the repeated signal strength would be nearly the same as the non-repeated signal strength at a particular receiving location. However, the delay-line repeater retransmits a signal not only at the received frequency, but also at other frequencies. This is because a received transmission is retransmitted at time intervals corresponding to the repeater switching frequency. Thus the repeater, in effect, originates frequency components not in the original received signal. For a given received signal, the largest repeater-originated

component of transmission has an energy equal to about one-fourth that of the output signal component which has the same frequency as the received signal.

A first simple step for minimizing the interference problem is to reduce the frequency range of the repeater to the minimum useful value by adding a bandpass filter within the delay-line loop, as shown in Fig. 2.

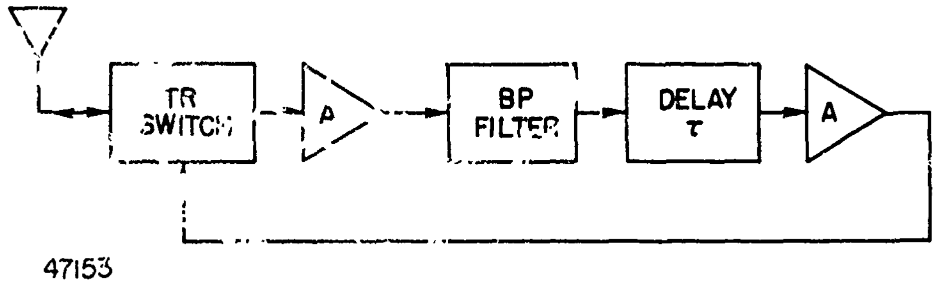


Fig. 2. FREQUENCY-LIMITED DELAY-LINE REPEATER.

The repeater-generated transmissions can be made less objectionable if they are made similar to random noise rather than to frequency-translated replicas of the received waveforms. It is planned to introduce such a noise-like property into the spurious generated frequencies by randomizing the lengths of the "receive" periods.

2. Repeater Performance Degradation Caused by Interference

When the repeater is used to retransmit incident waves originated by ionosphere sounders, the only significant effect produced in the repeater by HF signals other than the desired signal from the sounder is the gain suppression and intermodulation which occur if the peak power required for linear operation exceeds the capability of the repeater power amplifier. For the case where the received sounder-signal energy is considerably greater than the energy of all other signals within the repeater bandwidth there is no degradation from interfering signals, and the repeater gain can be set to such a value that the sounder signal is near the peak capability of the repeater power amplifier. If it is desired to increase the gain of the repeater further, this can be done if the sounder-transmitted signal can be reduced until the point is reached where the interfering signals are about equal to the sounder signal. Thus, in summary, to obtain a maximum in repeater visibility the following steps are taken:

1. The sounder signal is adjusted to obtain about unity in the ratio between the sounder signal and all other energy received by the repeater.
2. The gain of the repeater is increased to the point of saturation of the repeater power amplifier.

D. PERFORMANCE MONITORING

It is expected that an oscilloscope will be used to monitor in detail the operation of the prototype repeater. However, a number of similar repeaters will be constructed in the future, and it will probably be necessary to monitor their operation by means of a meter circuit. Such an arrangement would permit checking for proper repeater operation to be carried out by unskilled operators or by a telemetering system.

Adequate check of the repeater system would be obtained by measuring the following parameters:

1. Noise at the antenna terminal, with a 50 ohm terminator replacing the antenna and with the loop gain set at maximum. This check would verify proper operation of all the amplifiers, assuming proper operation of the switching circuits.
2. The percentage of time the TR switch is in the "transmit" position. This would verify proper switch operation.
3. The percentage of time the output amplifier is driven to near-saturation during operation. By setting the loop gain to keep this percentage low, one can be confident of accurately knowing the effective gain of the system.

III. HARDWARE DEVELOPMENT AND TESTS

A. PROTOTYPE TEST

A preliminary laboratory prototype of the delay-line repeater was assembled at the Stanford University radio field site in Bearden, Arkansas during the week of 11 November 1968. Figure 3 is a block diagram showing the equipment used.

The switch control, switches, and filters were laboratory-developed items. All other equipment was of standard commercial type. All switches were essentially the SPST type shown by the schematic diagram in Fig. 4. The "transmit" and "receive" switches shown in Fig. 4 were required since the isolation provided by the combined TR switch was not adequate.

The high-pass (HPF) and low-pass (LPF) filters which preceded the TR switch were added to restrict the repeater operation to frequencies useful for the backscatter tests and thus prevent interference to users of frequencies outside the range of interest. One would not want to put a narrow-band filter (BPF) ahead of the TR switch because the resultant energy storage would be likely to cause oscillation.

Backscatter ionograms were produced by transmitting from the Stanford Lost Hills site, and receiving at Los Baños [Ref. 3]. Figure 5 shows a typical backscatter ionogram with the repeater "echoes" clearly visible. The tunable bandpass filter and the balanced mixer were not used in this test. Because of the high sensitivity of the FMCW system to the phase-stable repeater signal, only 160 mW of energy at the desired frequency were required from the repeater for the ionogram in Fig. 5.

B. IMPROVED PORTABLE DESIGN

A compact and more efficient version of the delay-line repeater has been completed and installed in a vehicle.

The block diagram is shown in Fig. 6, and a photograph of the equipment in Fig. 7. The commercial amplifiers were replaced by integrated circuits where signal levels are low and by transistor amplifiers where signal levels are high. Filters may be added as in Fig. 3 if interference problems appear likely during use.

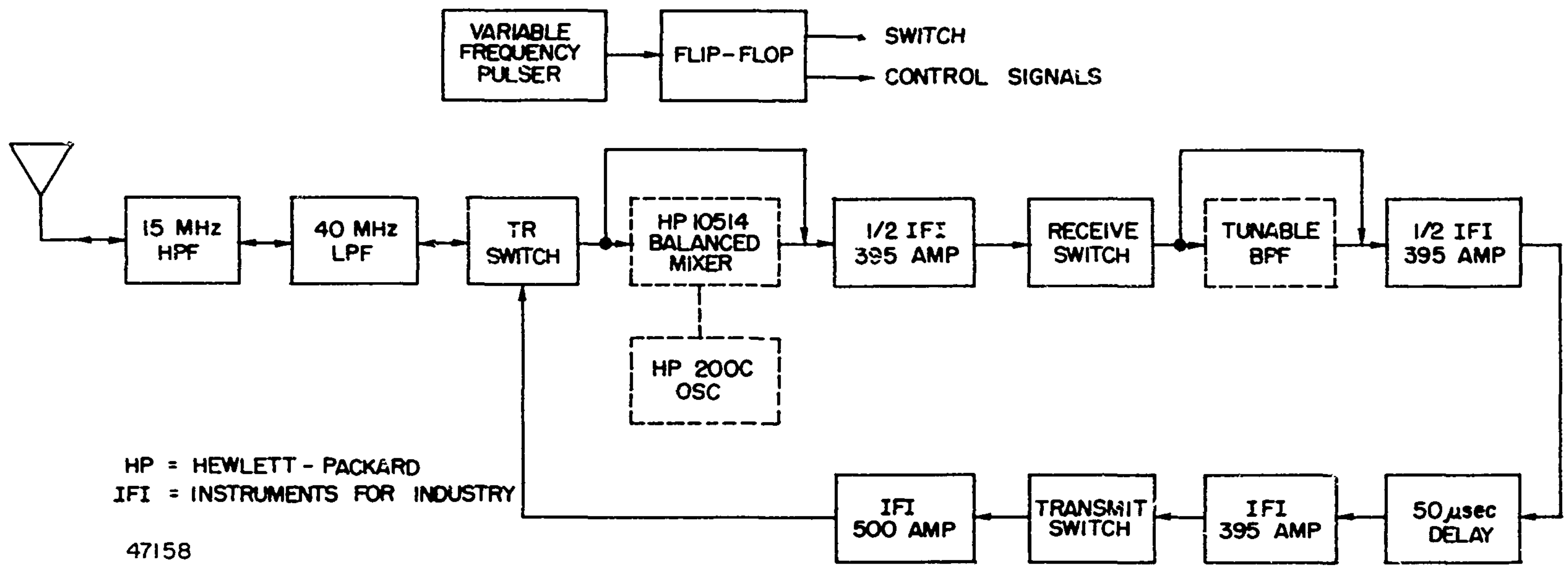


Fig. 3. BLOCK DIAGRAM OF TRANSPONDER PROTOTYPE.

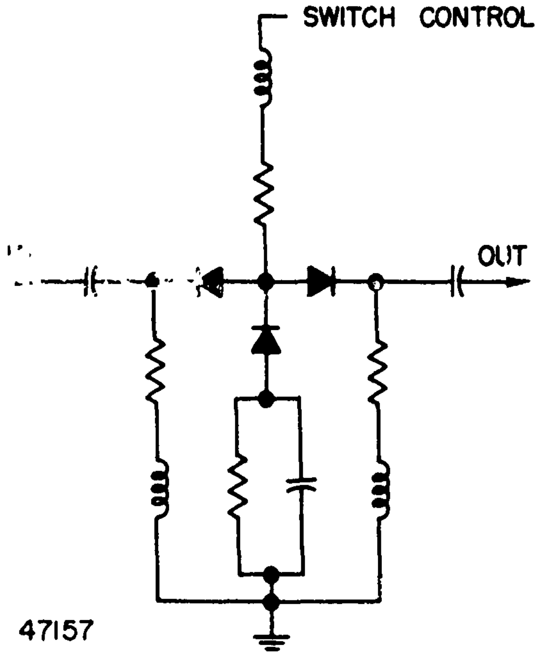


Fig. 4. TYPICAL SPST SWITCH CONFIGURATION.

All circuitry has been designed to operate from a +20 V supply. A small DC-to-DC converter develops -50 V for back bias of the diodes in the TR switch. The input power requirement is about 50 W.

The symmetrical flip-flop has been replaced by an astable multivibrator which gives the capability of independent adjustment for "transmit" and "receive" times. This independent adjustment feature will make it convenient to provide a random voltage determining "receive" time, and thereby impart a noise-like property to the sidebands generated by the switching process.

C. INTERFERENCE MEASUREMENTS

As pointed out in an earlier section of this report, the visibility for a given repeater power amplifier capability is determined by the amount of interference received by the repeater. Measurements were made at the Bearden field site to obtain data showing the magnitude of the interference received there in a wide bandwidth repeater. Table 1 gives

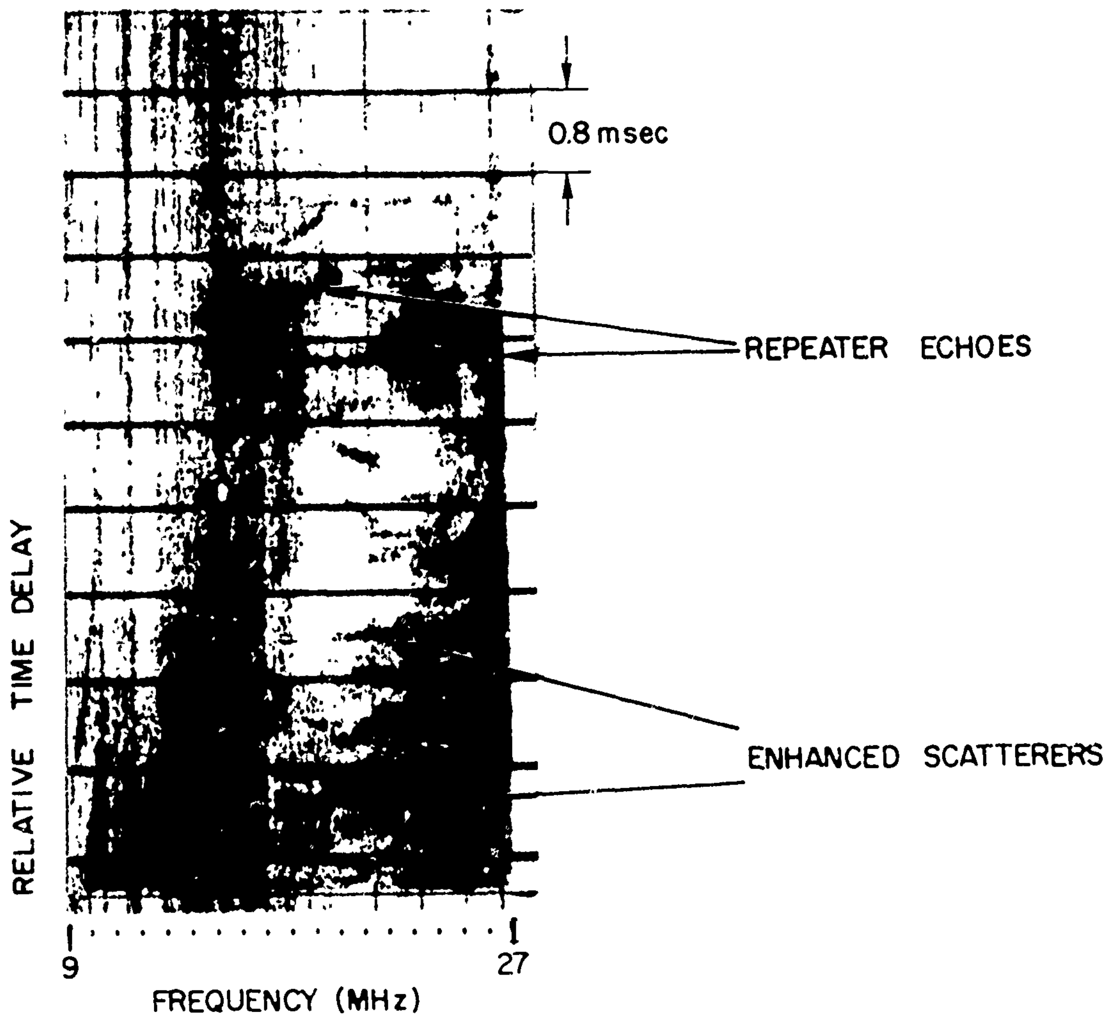


Fig. 5. BACKSCATTER IONOGRAM, LOST HILLS/LOS BAÑOS.

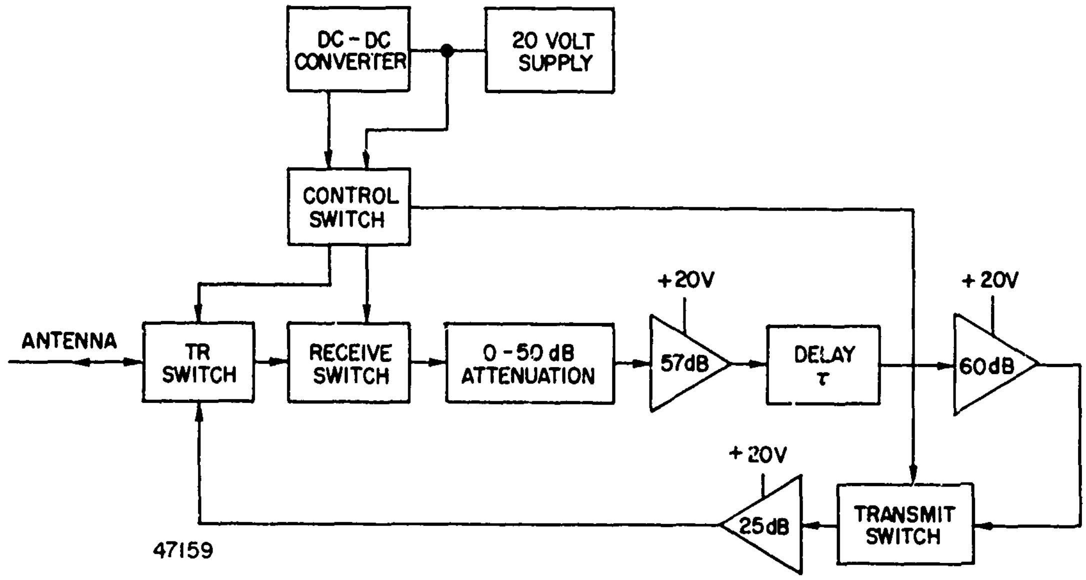
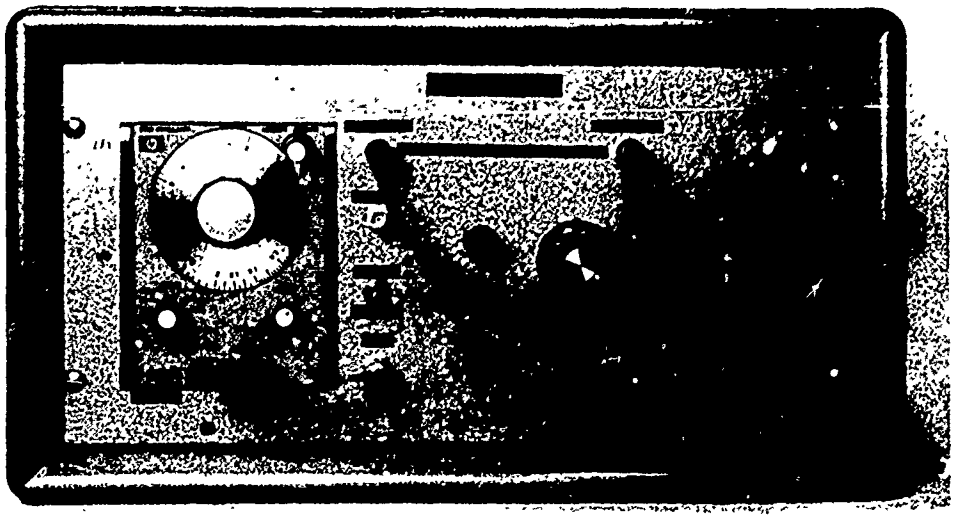


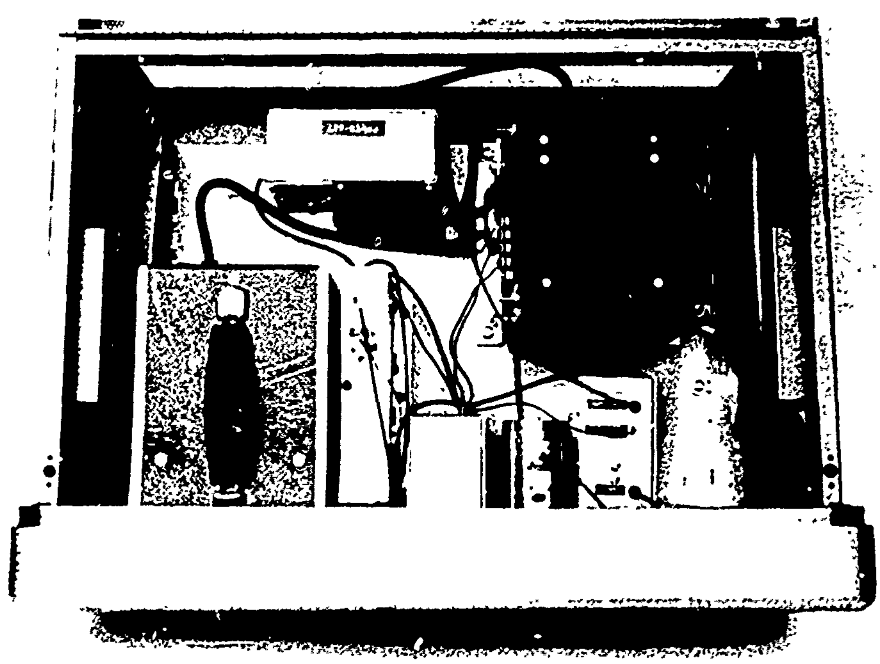
Fig. 6. COMPACT REPEATER BLOCK DIAGRAM.

the beamwidth and the frequency coverage for the antennas which were used to make the interference measurements. The "T-whip" is an 18 ft uncompensated whip mounted on top of the field-site trailer. The "G5-whip" is a 10 ft ground-mounted whip with four 50 ft ground radials. The "G5-whip" was compensated by a network in series to give a voltage standing wave ratio (VSWR) of less than 1.5 to 1 over the frequencies between 20 and 28 MHz. The repeater delay line has a lower cutoff frequency of 7 MHz, so that the Collins LPA coverage between 3 and 7 MHz did not contribute significantly to the noise measured.

The interference data are presented in Table 2 by recording the loop gain of the repeater which causes a 10 W power amplifier to clip about ten percent of the time. The significance of the 287 deg bearing is that this is the bearing toward Stanford's Los Baños, California field site.



a. Front view



b. Top view

Fig. 7. PORTABLE DELAY-LINE REPEATER.

TABLE 1

ANTENNA CHARACTERISTICS

Antenna	Beamwidth	Frequency Coverage
ITT-FTM	90°	7-27 MHz
Collins-LPA	60°	3-40 MHz
T-whip	-	-
G5-whip	-	21-28 MHz

TABLE 2

MAXIMUM PERMISSIBLE PORTABLE-REPEATER LOOP GAIN

Antenna	Direction	Loop Gain (dB)									
		1 April 1969			2 April 1969			4 April 1969			7 April 1969
		1000 CST	1200 CST	1400 CST	0900 CST	1130 CST	1600 CST	0900 CST	1130 CST	1600 CST	0900 CST
LPA	0°	88	86	85	84	83	81	85	85	82	82
"	90°	87	77	76	76	74	74	74	75	74	73
"	180°	90	85	83	83	82	82	80	79	79	81
"	270°	91	89	88	87	86	84	85	85	83	82
"	287°	87	85	87	87	85	81	84	83	78	83
ITT	287°	84	86	85	85	83	78	82	83	78	81
G5-whip	--	91	91	90	88	88	86	90	92	87	90
T-whip	--	81	83	81	31	77	76	79	82	75	80

IV. CONCLUSION

A. SUMMARY OF RESULTS

A single-antenna repeater for HF use has been constructed and tested. Figure 5 is a backscatter ionogram showing echoes resulting from the repeater. The repeater is compact enough to be easily transported by a car or an airplane. A photo showing the prototype repeater is reproduced in Fig. 7.

The portable feature of the single-antenna repeater is expected to be very useful in ionosphere research. A particular use will be to attempt to identify backscatter echoes which are caused by areas on the ground that reflect larger-than-average amounts of incident HF radiation. Some of these echoes are pointed out in Fig. 5.

B. CONCLUSIONS

The construction and operation of a single-antenna repeater can be accomplished in a relatively simple manner for ionosphere sounding systems using an FMCW waveform. Some interference to other users of the HF spectrum does occur; but this is not, in general, expected to be a serious problem for the following reasons:

1. The FMCW system is very sensitive to the phase-stable signal of the repeater, so that a relatively low repeater gain is sufficient for operation.
2. The repeater can be designed to randomize the interference which is generated by the pulse modulation. The resulting noise-like interference is not expected to be noticeable, particularly if the repeater is operated for only short periods of time in any particular location. (This is the expected mode of operation.)

REFERENCES

1. R. B. Fenwick and G. H. Barry, "HF Measurements Using Extended Chirp-Radar Techniques," Rept. SEL-65-058 (TR No. 103), Stanford Electronics Laboratories, Stanford, Calif., June 1965.

2. L. L. Peden, J. M. Lomasney and R. B. Fenwick, "A Flexible, HF Sweep-Frequency Sounder With Submicrosecond Resolution," Rept. SEL-68-088 (TR No. 140), Stanford Electronics Laboratories, Stanford, Calif., November 1968.

3. T. W. Washburn, "High Resolution HF Ground Backscatter Observations," URSI Fall Meeting, September 1968.

4. Private communication to author.

ONR-ARPA U-SERIES DISTRIBUTION LIST

NAVY

Chief of Naval Research
Department of the Navy
Washington, D.C. 20360
2 Attn: Code 418

Director
Naval Research Laboratory
Washington, D.C. 20390
1 Attn: Code 5320 (E. Zettle)
1 Attn: Code 5320 (J.M. Headrick)
1 Attn: Code 5432C (F.A. Polinghorn)
1 Attn: Code 2027
1 Attn: Code 5400 (L. Wetzel)

Chief of Naval Operations
Department of the Navy
The Pentagon
Washington, D.C. 20350
1 Attn: OP-07TE
1 Attn: OP-723E

Commander Naval Missile Center
Point Mugu, California 93041
1 Attn: Code N03022

Commander
Naval Weapons Center
China Lake, California 93555
1 Attn: Code 4025 (R.S. Hughes)

Commander
Naval Electronics Laboratory Center
San Diego, California 92152
1 Attn: Mr. H.J. Wirth
1 Attn: Library

Officer in Charge
Naval Weapons Center
Corona Laboratories
Corona, California 91720
1 Attn: Mr. V.E. Hildebrand

Director
Office of Naval Research Branch Office
495 Summer Street
Boston, Massachusetts 02210
1 Attn: Mr. Stan Curley

AIR FORCE

Headquarters, USAF
The Pentagon
Washington, D.C. 20330
1 Attn: AFNICAD (MAJ Nyquist)
1 Attn: AFRDDF

Headquarters, USAF
Office of Assistant Chief
of Staff, Intelligence
Washington, D.C. 20330
1 Attn: AFNICAA

Commander
Rome Air Development Center
Research & Technology Div.
Griffiss AFB, New York 13442
1 Attn: EMASO (S. DiGennaro)
1 Attn: EMAES (MAJ Wipperman)
1 Attn: EMASR (V.J. Coyne)
1 Attn: EMASA

Headquarters
Air Force Systems Command
Foreign Technology Division
Wright-Patterson AFB
Ohio 45433
1 Attn: TDDBP (Mr. Zabetakis)
1 Attn: TDEED (W.L. Picklesimer)
1 Attn: TDDC

Headquarters
Air Force Systems Command
Research & Technology Division
Bolling Air Force Base
Washington, D.C. 20332
1 Attn: RTTC

Headquarters
USAF Security Service (OSA)
San Antonio, Texas 78241
1 Attn: ODC-R (W.L. Anderson)

ONR 64
11-69

ONR-ARPA U-SERIES DISTRIBUTION LIST

AIR FORCE (Cont.)

Headquarters
Air Defense Command
Ent AFB
Colorado Springs, Colo. 80912
1 Attn: NPSD-A
1 Attn: ADLPC-2A (LCOL R.J. Kaminski)
1 Attn: ADOAC-ER
1 Attn: NFLC-AP

Electronics Systems Division (ESSL)
L.G. Hanscom Field
Bedford, Massachusetts 01731
1 Attn: Code 440L

Headquarters SAC (OAI)
Offutt Air Force Base
Omaha, Nebraska 68113
1 Attn: Mrs. E. G. Andrews

Headquarters, AFCRL
L.G. Hanscom Field
Bedford, Massachusetts 01731
1 Attn: CRUI
1 CRUP (Dr. G.J. Gassman)

Headquarters
U.S. Air Force
Air Force Western Test Range
Vandenberg AFB, Calif. 93437
1 Attn: WTGT

Headquarters, USAF AFTAC
Washington, D.C. 20333
1 Attn: TD-3

Headquarters
Air Weather Service
Scott AFB, Illinois 62265
1 Attn: MAJ T.D. Damon (AWVDC)

ARMY

Office of the Assistant Chief
of Staff for Intelligence
Department of the Army
The Pentagon, Room 2B 457
Washington, D.C. 20310
1 Attn: Mr. Joseph Grady

U. S. Army SLAG
The Pentagon, Room 1B 657
Washington, D.C. 20310
1 Attn: Mr. N.R. Garofalo

Chief
Army Security Agency
Arlington Hall Station
Arlington, Virginia 22212
1 Attn: Mr. R.R. Neill
1 Attn: IAOPS-O(SA)

Commanding Officer
Army Security Agency
Processing Center
Vint Hill Farms Station
Warrenton, Virginia 22186
1 Attn: LT Alan Bagully
1 Attn: Technical Library

Commander
U.S. Army
Electronics Warfare Lab
Mt. View Office, USAEC
P.O. Box 205
Mt. View, California 94040
1 Attn: Mr. Joseph Bert

U.S. Army Foreign Science &
Technology Center
Munitions Building
Washington, D.C. 20315
1 Attn: Communications &
Electronics Division

Commanding General
U.S. Army Missile Command
Redstone Arsenal, Alabama 35809
1 Attn: AMSMI-RES

DEPARTMENT OF DEFENSE

Director
Advanced Research Projects Agency
The Pentagon
Washington, D.C. 20301
1 Attn: Mr. Alvin Van Every

ONR-ARPA U-SERIES DISTRIBUTION LIST

DEPARTMENT OF DEFENSE (Cont.)

Office of the Assistant Director
Intelligence & Reconnaissance
Office of the Director of Defense
Research & Engineering
The Pentagon, Room 3E 119
Washington, D.C. 20301
1 Attn: Mr. H. A. Staderman

Director
National Security Agency
Fort George G. Meade
Maryland 20755
1 Attn: R-344(Mr. C. Gandy)
1 Attn: C3-TDL

Deputy Director
Research & Technology
Office of the Director of
Defense Research & Engineering
The Pentagon, Room 3E 1030
Washington, D.C. 20301
1 Attn: Dr. C. W. Sherwin

Office of the Assistant Director
(Defense Systems)
Defense Research & Engineering
The Pentagon, Room 3D 138
Washington, D.C. 20301
1 Attn: Mr. Daniel Fink

Director
Defense Intelligence Agency
The Pentagon, Room 3B 259
Washington, D.C. 20301
1 Attn: DIAC -4
1 Attn: DIAST-2B

Director
Weapons Systems Evaluation Group
Office of the Director of Defense,
Research & Engineering
1 Washington, D.C. 20301

Defense Documentation Center
Cameron Station
Alexandria, Virginia 2231
20 Attn: Document Control

National Aeronautics & Space
Administration
Ames Research Center
Moffett Field, California 94035
1 Attn: Dr. Kwok-Long Chan
1 Attn: Mr. Lawrence Colin

OTHERS

ITT Electro-Physics Laboratories,
Incorporated
3355 52nd Avenue
Hyattsville, Maryland 20781
1 Attn: Mr. W.T. Whelan

Institute for Defense Analyses
400 Army-Navy Drive
Arlington, Virginia 22202
1 Attn: Dr. Charles Lerch

MITRE Corporation
E Building, Room 353
Bedford, Massachusetts 01730
1 Attn: Mr. W.A. Whitcraft, Jr.
1 Attn: Mr. Wm. Talley

RAND Corporation
1700 Main Street
Santa Monica, Calif. 90406
1 Attn: Dr. Cullen Crain
1 Attn: Library

Raytheon Co.
Research Div. Lib.
28 Seyon St.
1 Waltham, Mass. 02154

Raytheon Company
Spencer Laboratory
2 Wayside Road
Burlington, Massachusetts 01803
1 Attn: L. C. Edwards

Stanford Research Institute
Menlo Park, California 94025
1 Attn: Dr. David Johnson

ONR 64
11-69

ONR-ARPA U-SERIES DISTRIBUTION LIST

OTHERS (Cont.)

Sylvania Electronics Systems
Electronics Defense Laboratory
P.O. Box 205
Mt. View, California 94094
1 Attn: Dr. James Burke

Mr. Thurston B. Soisson
Box 8164 SW Station
1 Washington, D.C. 20024

Astrophysics Research Corporation
10889 Wilshire Boulevard
Los Angeles, California 90024
1 Attn: Dr. Alfred Reifman

Institute of Science & Technology
The University of Michigan
P.O. Box 618
Ann Arbor, Michigan 48105
1 Attn: BAMIRAC Library

Bendix Corporation
Bendix Radio Division
Baltimore, Maryland 21204
1 Attn: Mr. John Martin

AVCO Systems Division
Lowell Industrial Park
Lowell, Massachusetts 01851
1 Attn: Mr. Sidney M. Bennett

U.S. Department of Commerce
ITSA-ESSA
Boulder, Colorado 80302
1 Attn: Mr. William Utlaut
1 Attn: Mr. L.H. Tveten
1 Attn: Mr. W.A. Klemperer,
Div. 530, ESSA

Page Communications, Inc.
3300 Whitehaven Street NW
1 Washington, D.C. 20008
1 Attn: Mr. David Fales , III

Massachusetts Institute of Technology
Lincoln Laboratory
P.O. Box 73
Lexington, Massachusetts 02173
1 Attn: Dr. J.H. Chisholm

Massachusetts Institute of
Technology
Center for Space Research
Building 33-109
Cambridge, Massachusetts 02138
1 Attn: Dr. J.V. Harrington

Institute for Defense Analyses
100 Prospect Avenue
Princeton, New Jersey 08540
1 Attn: Dr. Edward Frieman

University of California
Mathematics Department
Berkeley, California 94720
1 Attn: Dr. E.J. Pinney

University of California
Electronics Research Laboratory
Berkeley, California 94720
1 Attn: Prof. D.J. Angelakos

Battelle-Defender
Battelle Memorial Institute
505 King Avenue
1 Columbus, Ohio 43201

HRB-Singer, Incorporated
Science Park
P.O. Box 60
State College, Pennsylvania 16801
1 Attn: Library

Pickard & Burns, Research Dept.
103 Fourth Avenue
Waltham, Massachusetts 02154
1 Attn: Dr. J.C. Williams

Sylvania Electronic Systems
Applied Research Laboratory
40 Sylvan Road
Waltham, Massachusetts 02154
1 Attn: Library

ONR-ARPA U-SERIES DISTRIBUTION LIST

OTHERS (Cont.)

Department of Electrical Engineering
Radio Location Research Laboratory
University of Illinois
Urbana, Illinois 61803
1 Attn: Dr. Albert Bailey

Arecibo Ionospheric Observatory
Box 995
Arecibo, Puerto Rico 00613
1 Attn: Librarian

The University of Texas
Electrical Engineering Research Lab.
Route 4, Box 189
Austin, Texas 78756
1 Attn: Mr. C.W. Tolbert

Rice University
Fondren Library
P.O. Box 1892
1 Houston, Texas 77001

Purdue University
Library
1 West Lafayette, Indiana 47906

Telcom, Incorporated
8027 Leesburg Pike
McLean, Va. 22101
1 Attn: Mr. J.D. Ahlgren,
Vice President

IBM
Armonk, New York 10504
1 Attn: S.W. Woolver
(Info Retrieval Specialist)

General Telephone & Electronics
Laboratories, Inc.
208-20 Willets Point Boulevard
Bayside, New York 11360
1 Attn: Mr. George H. Kiesewetter

Applied Physics Laboratory
The Johns Hopkins University
8621 Georgia St.
1 Silver Spring, Md.

Barry Research
934 E. Meadow Drive
Palo Alto, California 94303
1 Attn: Dr. George H. Barry

RCA
Moorestown, N.J.
1 Attn: Mr. Charles Bertles

General Electric Co.
Syracuse, N.Y.
1 Attn: Mr. Gary Nelson

Sanders Associates
95 Canal St.
Nashua, New Hampshire
1 Attn: Mr. Eugene Novak

Mr. Robert F. Schulz
Radio Physics Lab - SRI
Bldg. 44
Ravenswood Dr.
Menlo Park, Calif. 94025

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Stanford Electronics Laboratories
Stanford University, Stanford, California

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

A SINGLE-ANTENNA REPEATER FOR HF RADIO PROPAGATION STUDIES

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Report No. 154, October 1969

5. AUTHOR(S) (First name, middle initial, last name)

A. C. Phillips

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO OF REFS
October 1969	21	4

8a. CONTRACT OR GRANT NO	9a. ORIGINATOR'S REPORT NUMBER(S)
Nonr-225(64) NR 088 019	TR No. 154 SEL-69-064
b. PROJECT NO	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Office of Naval Research, Field Projects Programs, Washington, D. C. 20360.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Office of Naval Research

13. ABSTRACT

The purpose of the work described in this report was to develop and test a compact, portable, calibrated single-antenna repeater which has application to HF radio propagation studies. For example, high-frequency backscatter ionograms--depending on the terrain--generally show one or more discrete range intervals where the returned energy is appreciably greater than the general noise-like return from other ranges. The ground features which cause these areas of enhanced HF energy reflection are not as yet fully understood. A portable repeater is capable of being operated in those areas where such reflections exist so that a direct comparison can be made between the repeated signal and the natural echoes. The repeater described in this report is especially useful with FMCW sounding waveforms.

A fundamental problem in building any repeater is the avoidance of oscillations when it is attempted to retransmit an amplified signal with receiving and transmitting antennas in the same locality. The solution adopted in this case consists of switching one antenna rapidly between transmitting and receiving modes. The received signal is amplified, then stored for the duration of the receiving period. At the end of that period it is transmitted. The act of switching in this way does not seriously degrade the operation of the repeater; in fact, it confers certain unique advantages.

The portable repeater described herein has been tested in the field, and has been found to perform satisfactorily.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
REPEATER						
CALIBRATOR						
ENHANCED REFLECTORS						
IONOSPHERE BACKSCATTER SOUNDING						